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**WATER ENTRY INTO THE MAC
200 IMMERSION SUIT DURING
SIMULATED PARACHUTE JUMP
AND DRAG TRIALS**

Michel B. Ducharme
John A.M. Thompson

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Toronto, Ontario
Canada M3M 3B9

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EXECUTIVE SUMMARY

The MAC 200 immersion suit newly developed by Mustang Survival (Richmond, B.C.) has recently been considered a potential replacement suit for the constant wear dry immersion suit currently used by Canadian Forces aircrew. The objective of the present evaluation trial was to evaluate the effectiveness of the new neck seal concept by measuring water leakage into the MAC 200 suit during a simulated parachute jump into water followed by a 15 s drag. Four male aircrew members volunteered to participate in the study. On Day 1 they jumped from the back of a boat (about 30 cm above the water) moving at a speed of $5 \text{ km} \cdot \text{h}^{-1}$ and were dragged for 15 sec. On Day 2, the aircrew jumped from a platform 3 m above water to simulate the speed of parachute entry and were immediately attached to a line and dragged behind a boat for 15 sec at a speed of $5 \text{ km} \cdot \text{h}^{-1}$. Before and after the jump/drag procedure the aircrew were weighed to estimate the amount of water leakage into the suit. The results showed that when the neck and wrist seals of the suit were closed properly before the entry into the water, no leakage was observed following the jump/drag procedure on both testing days. When the seals were closed only after the jump (but before the drag) or left open during the jump and drag procedures, water leakage of $0.64 \pm 0.23 \text{ kg}$ and $1.49 \pm 0.47 \text{ kg}$ were measured, respectively. It was concluded that under ideal conditions, i.e., when the seals of the MAC 200 are properly closed, a simulated parachute water entry and drag will not cause significant water leakage into the suit. This suggests that the nearly-dry suit concept of the MAC 200 has good potential for short immersion period under those conditions, provided the neck seal is improved.

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ABSTRACT

Mustang Survival has develop a new concept of immersion suit: the nearly-dry MAC 200. The suit is of one-piece design with a Nomex and Gore-Tex® membrane shell, a closed-cell insulation liner, and a neck seal that can be closed using a ratchet tightening system. The objective of the present study was to evaluate the MAC 200 suit for water leakage under conditions simulating a parachute water entry and drag over water. Four male subjects were selected with proper neck sizes to fit the neck seal of the suit. In Phase 1, the subjects, attached to a line, jumped from a height of 30 cm above water from the back of a boat moving at $5 \text{ km} \cdot \text{h}^{-1}$ and were dragged for 15 sec. In Phase 2, the subjects jumped into the water from a 3 m platform to simulate the speed of parachute entry and were immediately attached to a line and dragged behind a boat for 15 sec at a speed of $5 \text{ km} \cdot \text{h}^{-1}$. The subjects were weighed to $\pm 5 \text{ g}$ on an electronic scale before and after the jump/drag procedures to estimate the amount of water leakage into the suit. The results showed that when the neck and wrist seals of the suit were closed properly before the entry into the water, no leakage was observed following the jump/drag procedure for both Phases. When the seals were closed only after the jump (but before the drag) or left open during the jump and drag procedures to simulate different seal closure scenarios, water leakage of $0.64 \pm 0.23 \text{ kg}$ and $1.49 \pm 0.47 \text{ kg}$ were measured, respectively. It was concluded that under ideal conditions, i.e., when the seals of the MAC 200 are properly closed, a simulated parachute water entry and drag will not cause significant water leakage into the suit. When time or stress is a factor that precludes properly closing the neck, then the performance of the MAC 200 suit is closer to that of a leaky dry suit. This suggests that the nearly-dry suit concept of the MAC 200 has good potential for short immersion periods under those conditions, provided the neck seal is improved.

INTRODUCTION

The MAC 200 immersion suit is a "nearly-dry" immersion suit newly developed by Mustang Survival (Richmond, BC.) for possible replacement of the current constant wear dry immersion suit used by Canadian Forces (CF) aircrew. The term "nearly-dry" has been used by Mustang Survival to describe the new suit because it incorporates a series of seals for the neck and wrists that can be easily and quickly closed just prior to water entry to keep the water getting into the suit to a minimum. It can also accept a certain amount of water leakage before compromising the insulation value of the suit necessary for survival.

The suit is a one-piece design with stretchable Gore-Tex® socks comprising a Nomex outer shell, a Gore-Tex® inner membrane, and a removable breathable nylon-covered insulative foam liner. The neck seals are of a split-neck seal design with a one-piece ratchet tightening system. The wrist seals consist of a two-layer tug-tightening design with Velcro®. According to recent testing on a thermal manikin, the new suit possesses the good thermal properties of a dry suit (around 0.94 immersed Clo; The CORD Group, 1997) without the problems of neck discomfort in the cockpit and difficulty with maintenance.

A recent trial at the Institute of Marine Dynamics (National Research Council of Canada, St. John's, NF) showed that during water immersion in calm and turbulent conditions, water ingress into the suit was highly dependent on the proper fit of the neck seals of the MAC 200 suits, although the neck seal could accommodate a range of neck sizes. Indeed in calm water condition, water ingress into the suit was on average about 6.5 kg for female subjects with an average neck size of 32 cm, and only about 0.4 kg for the male subjects with an average neck size of 39 cm (see Fig. 1). The water leakage worsened for the male subjects during turbulent water conditions to about 0.8 l but peaked very quickly at 20 cm wave height. It was concluded from that study that the water leakage into the MAC 200, when a proper size of neck seal is used, is much less than in a standard wet suit, which is usually flooded with water following an immersion, this corresponds more to the amount of water found in a typical dry suit following a swim test (Light et al, 1987).

During an emergency aircraft ejection over water, the aircrew will enter water with its parachute at a speed of about $6 \text{ to } 7.5 \text{ m} \cdot \text{sec}^{-1}$ and, if it is done during a windy condition, the aircrew may be dragged by its parachute over the water for few seconds until

the pilot releases the parachute harness. This will increase the likelihood of water ingress

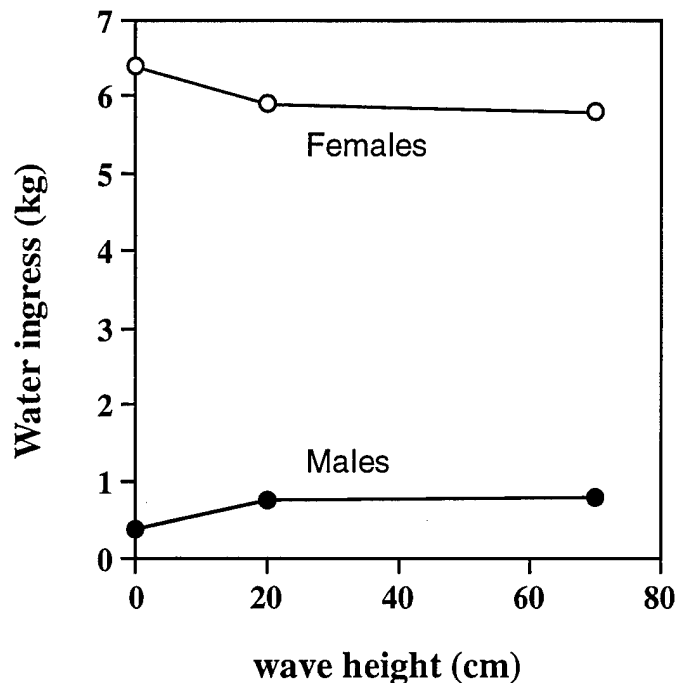


Figure 1. Data from a recent trial at the Institute of Marine Dynamics presenting the average water ingress into the MAC 200 immersion suit during a 1 hr immersion at different wave conditions while wearing the LP/SV vest. The seals of the MAC 200 suit were closed prior to the water immersion.

into the suit, which is additional to the water leakage that will occur during the long term immersion phase that will follow. No information is available about the water ingress into the MAC 200 suit following an entry into water with a parachute and following a drag. The objective of the present study was, therefore, to quantify the water leakage into the MAC 200 immersion suit following a parachute entry and a drag simulation for different seal closure configurations while wearing the current Life Preserver/Survival Vest (LP/SV). This study provides complementary data about water leakage into the MAC 200 immersion suit under various aircrew operational emergency conditions.

MATERIALS AND METHODS

The trial was performed at the Search and Rescue School in Comox, B.C., at the end of August 1997 and was conducted over a two-day period.

Subjects. Four male CF aircrew subjects were used during the evaluation and Table 1 presents their anthropometric characteristics. The subjects were selected with a neck size of 37 cm and above to properly fit the neck seal of the MAC 200 immersion suits. All subjects were volunteers and had operational experience with the standard procedures during an emergency aircraft evacuation. They all had previous parachute and parachute-drag training including training on the release of a parachute harness during a drag over water.

Table 1. Anthropometric characteristics of the aircrew subjects

Subject #	Age (y)	Height (cm)	Weight (kg)	Neck size (cm)
1	27	175	82	38.5
2	27	180	73	37.5
3	25	183	91	40.5
4	32	180	84	39.0
Mean	27.8	179.5	82.5	38.9
±SD	3.0	3.3	7.4	1.3

Procedures. The study was divided into two phases having three different seal closure conditions. During the two phases, the MAC 200 immersion suit, a LP/SV vest, a T-33 parachute harness assembly, a 190A aircrew helmet and a pair of neoprene boots were worn by the subjects over a T-shirt and shorts.

Phase 1 consisted of simulating a 15 sec parachute drag from the back of a 16 m boat in motion at a speed of $5.0 \text{ km} \cdot \text{h}^{-1}$. The 15 sec drag time was used throughout the trial as an estimated time for a trained aircrew to get out of his/her parachute harness. A drag speed of $5 \text{ km} \cdot \text{h}^{-1}$ was used to represent a realistic speed during a parachute drag. The subjects, attached to a 8 m detachable line to the boat, jumped from the back of the boat in motion from approximately 30 cm above water and were dragged for 15 sec. An electronic weighing scale with a resolution of $\pm 5 \text{ g}$ was used on the deck of the boat to weigh the subjects before and immediately after the drag. Because of the movement of the boat, the reading on the scale fluctuated by about $\pm 0.5 \text{ kg}$. The final reading was a subjective average obtained over a period of 10 sec. For each experimental condition, a new dry immersion suit was used by each subject. The conditions tested were as follows:

Condition 1: This condition provided the best case scenario that would minimize the water entry into the suit. It simulated an aircrew who ejected into water with an inflated LP/SV (which will minimize the depth and duration of the underwater immersion) and closed neck and wrist seals before being dragged by his parachute. The subjects were dragged for 15 sec and quickly taken out of the water and weighed.

Condition 2: This condition provided a balance between the best and worst case scenario. It simulated an aircrew ejecting into water with an inflated LP/SV but with open neck and wrist seals (because of lack of time to close the seals before ejection or during the parachute descent). As quickly as possible after water entry, the subjects closed the neck and wrist seals prior to the 15 sec drag. After the drag, each subject was quickly taken out of the water and weighed.

Condition 3: This condition provided the worst case scenario that would maximize water entry into the suit. It simulated an aircrew who ejected unconscious into the water with an uninflated LP/SV and open neck and wrist seals before being dragged by its parachute. Upon water entry, the LP/SV was automatically inflated via an Automatic Inflation Device (AID). The subjects were dragged with their open neck and wrist seals for 15 sec. Immediately upon completion of the 15 sec drag, the subjects closed their wrist seals to prevent water leaking out of the suit and were quickly taken out of the water and weighed.

The objective of Phase 2 was to simulate a parachute entry into water followed by a drag and to measure the water ingress into the MAC 200 suit following the procedures. Parasailing with a parachute was planned; however, poor weather conditions prevented this portion of the trial. Instead, the parachute entry was simulated by a jump from a platform fixed on land approximately three meters above the water (estimated speed of entry at $7.7 \text{ m} \cdot \text{s}^{-1}$) and was immediately followed by a drag period of 15 sec behind a 6.8 m jet boat moving at a speed of $5 \text{ km} \cdot \text{h}^{-1}$. The drag started within 20 sec after water entry, which was the time it took to attach the subject to a line attached to the jet boat. An electronic weighing scale with a resolution of $\pm 5 \text{ g}$ was used to weigh the subjects before and immediately after the drag. The scale was positioned on a firm, stable and leveled surface. Before entering the water for the test, subjects saturated the outsides of their immersion suits with water. This was done by immersing the subjects up to their necks in water for a period of 2 minutes. This procedure allowed for a precise determination of the amount of water entering the suit during the tests to account for the water on the outside of the suits by subtracting the weight of the saturated system (subject and suit but without the boots) before the jump/drag from the post jump/drag weight of the same system. For each experimental condition, a new dry suit was used for each subject, and the suit saturation procedure was followed. The same experimental conditions as in Phase 1 were used.

Phase 2, in contrast to Phase 1, provided an estimation of the water ingress into the suit following the combined action of a parachute entry and a parachute drag.

RESULTS

Phase 1. Figure 2 presents the water added to the outside and inside of the suit, in addition to the inside of the neoprene boots following the 15 sec drag for the three conditions. From examination of the inside of the suit, no water leaked into the MAC 200 during the drag under condition 1 (closed seals). The observed water addition of 1.5 ± 0.3 kg (mean \pm SD) was, therefore, limited to the outside of the suit and inside the boots. By subtracting that amount of water from the other two conditions, the results show that about 0.3 and 0.4 kg of water ($1.8 - 1.5$; $1.9 - 1.5$) leaked into the suit in conditions 2 and 3, respectively.

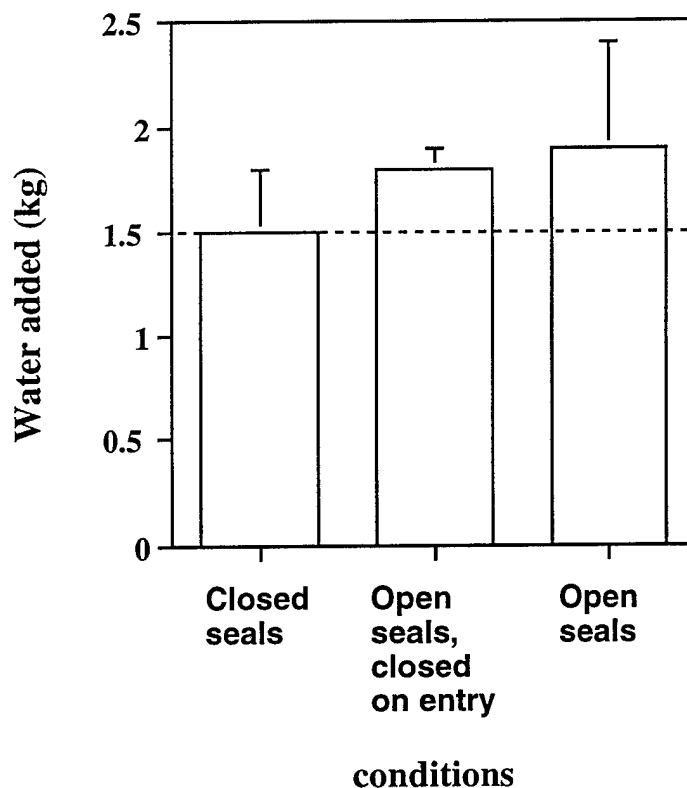


Figure 2. Average (\pm SD) water added to the MAC 200 immersion suit system (which includes the outside and inside of the suit and the inside of the neoprene boots) for the four subjects following a 15 sec drag at $5 \text{ km} \cdot \text{h}^{-1}$ for the three conditions tested. The amount of water added above the dashed line represents an estimation of the water ingress into the MAC 200 immersion suit.

Phase 2. Figure 3 presents the water ingress into the suit following the 3 m jump and 15 sec drag for the three conditions. From examination of the inside of the suit, virtually no water entered the MAC 200 following the jump and drag under the condition 1. This is confirmed by the 0.03 ± 0.09 kg of water ingress measured in condition 1 with the weight difference, and confirms the results obtained in condition 1 of Phase 1. Under conditions 2 and 3, however, a 0.64 ± 0.23 kg and 1.49 ± 0.47 kg water ingress were measured from the weight difference. Because the seals of the suit were open before the jump into the water and closed just before the drag, the result of condition 2 (0.64 kg) represents the water ingress into the suit from the action of the jump only. On the other hand, because the seals of the suit were not closed at all before the jump or the drag, the difference between the water ingress obtained in condition 3 and the one from condition 2 represents the water entry into the suit from the action of the drag only ($1.49 - 0.64 = 0.85$ kg).

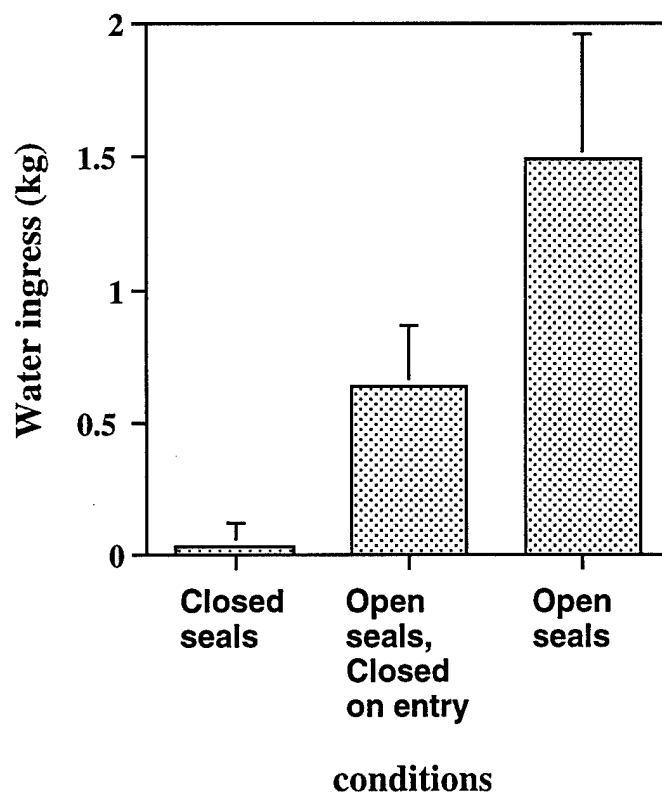


Figure 3. Average (\pm SD) water ingress into the MAC 200 suit for the four subjects following a jump from 3 m above water and a 15 sec drag at $5 \text{ km} \cdot \text{h}^{-1}$ for the three conditions tested.

The water leakages are larger during Phase 2 as compared to those of Phase 1 except for condition 1, probably because of the higher jump which allowed the subjects to stay longer under water, increasing, therefore, the chances of water leakage into the suit.

DISCUSSION

The results show that when the neck seal of the MAC 200 fits the neck of the subject properly and the seals are all closed before entry into water, a jump from 3 m above water followed by a 15 sec drag at a speed of $5 \text{ km} \cdot \text{h}^{-1}$ does not cause any significant water leakage into the suit. This observation supports the claim from the manufacturer that the suit behaves like a nearly-dry suit. This statement is true only under ideal conditions, i.e., when a proper neck fit is achieved, when the subject is not under stress and has the time to properly close the neck and wrist seals, and when the subject has some previous training with the neck seal mechanism to optimize the effectiveness of the seal around the neck. Those conditions are not always met all the time during emergency situations where a crew or person may be unconscious following the aircraft ejection or may not have the time to properly close the neck and wrist seals before entry into water. The results of this study show that in those less-than-ideal conditions, the water leakage into the MAC 200 suit can vary from 0.6 kg to 1.5 kg depending upon when or if the seals were closed during the jump/drag procedure. The performance of the suit in those conditions is closer to that of a leaky dry suit than a dry suit in good order, but not as bad as a wet suit.

The leakage observed in the present study represents only the water ingress following a jump/drag procedure which lasts less than a minute. This amount of leakage will add to the water ingress occurring during the longer term water immersion that will follow. A previous trial has shown that about 0.8 kg of water can leak into the suit during a 1 hr immersion in turbulent water despite good fitting and closed neck and wrist seals.

In a hypothetical condition where an aircrew is able to close the neck and wrist seals just after parachute water entry but before a 1 hr immersion in turbulent conditions (70 cm wave height), the expected water leakage will be around 1.4 kg (0.64 kg from the water entry and 0.8 kg from the 1 hr immersion). It was observed from thermal manikin testing under similar conditions that the suit will lose 41% of its thermal insulation because of the water leakage (total of 1.2 kg leakage; The CORD Group, 1997) as compared to a decrease in thermal resistance of 44% for the current CF constant wear dry immersion suit under milder conditions (smaller leakage of 1.0 kg and smaller wave height

of 20 cm; The CORD Group, 1991). This tends to support the claim from the manufacturer that the degradation of the insulation due to water contamination is not as pronounced for the closed cell of the MAC 200 insulation liner as compared to the open cells of the insulation liner of the constant wear dry immersion suit. As a result, a water leakage greater than 0.2 kg (which has been set as a maximum acceptable limit of leakage into a dry suit according to the International Maritime Organisation, 1984) may be more acceptable in the MAC 200 suit than in a dry immersion suit.

It was found during condition 2 that the aircrew subjects had some difficulty distinguishing between the pull-tab of the immersion suit zipper and the pull-tab of the neck seal ratchet system. Both pull-tabs are situated on the left side of the neck area, and it was noticed by the aircrew that when normally wearing gloves during flight operation, it would be difficult to differentiate between the two pull-tabs.

It is concluded that under ideal conditions, i.e., when the wrist but particularly the neck seal are properly closed, a simulated parachute water entry and drag will not cause significant water leakage into the MAC 200 immersion suit. This observation suggests that the concept of nearly-dry MAC 200 immersion suit has good potential during short immersion period.

RECOMMENDATIONS

Based on the results of the present study, it is recommended to:

1. move the neck seal pull-tab or the main zipper of the MAC 200 suit to the right side of the neck;
2. further improve the neck seal closure mechanism of the suit to facilitate its operation and to optimize its effectiveness during the stressful conditions of an aircraft evacuation where time and stress are limiting factors;
3. further improve the neck seal closure to accommodate a wider variety of neck sizes; and
4. further test the MAC 200 immersion suit for water leakage during long immersion period (several hours) in rough sea conditions and to evaluate the impact of water leakage on the suit thermal insulation and protection.

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